Asymmetry in atlas bone specimens: a pilot study using radiographic analysis

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Received 25 March 2008; received in revised form 20 August 2008; accepted 12 December 2008

Key indexing terms:

Chiropractic;
Cervical atlas

Abstract

Objective: Vertebral asymmetries can present a challenge to analysis of the anatomical and biomechanical misalignment component of chiropractic vertebral subluxation. The objective of this study was to determine the extent of asymmetry among 10 natural bone atlas specimens using radiographic analysis.

Methods: Ten natural atlas bone specimens' images were recorded using a digital radiographic system, and evaluations were made by 2 independent examiners using the system's software. Mean differences, standard deviations, and agreements were evaluated in regard to bilateral differences.

Results: The mean bilateral difference for both examiners was 0.96 mm, with a standard deviation of ± 0.67 mm. There were no statistically significant differences between the mean values for left and right measurements.

Discussion: The mean of 0.96 ± 0.67 mm indicates that measurements up to 1.63 mm (1 SD) or 2.30 mm (2 SDs) are clearly within a reference range of variation for this sample. This information could be used to assist the clinician measuring lateral misalignment of the atlas in determining the amount of expected normal asymmetry for the individual patient before concluding that lateral misalignment of the atlas is present.

Conclusions: These 10 specimens showed an average difference of $0.95 \text{ mm} \pm 1 \text{ SD}$ (0.67 mm) or 2 SDs (1.34 mm) between the left and right sides of the atlas vertebrae. Differences found on radiographs may be due to asymmetry and not actual misalignment. On the average, for these 10 vertebra specimens, a lateral disposition of 1.62 mm on either side should be allowed when arriving at a conclusion for lateral displacement of the atlas.

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Introduction

Asymmetry in radiographic analysis is a topic of interest for chiropractors.^{1,2} In regard to the atlas (C1) vertebra, the asymmetry reported in earlier chiropractic literature pertains to differences of lateral mass height.² More recent literature also indicates that the atlas vertebra is asymmetrical.³⁻⁷ Because of vertebral asymmetry, the question arises as to how this might affect analysis. For example, if a vertebra is measured to exhibit 1 mm of misalignment but this millimeter may be due to normal asymmetry, the vertebra may not be misaligned at all. This phenomenon has also been noted in a study regarding scoliosis, where measurements of lateral displacement of 1° to 6° were “associated with non-scoliotic spines.”⁸

The base posterior (BP) radiograph has been recommended to prevent errors regarding asymmetry,⁹ but the question remains as to how much asymmetry should be allowed before the clinician can say that actual lateral displacement exists in a given patient. In chiropractic radiographic analysis, the BP radiograph and anterior-posterior open mouth (APOM) radiograph are used to determine lateral misalignment of atlas by comparing the atlas alignment relative to the occipital condyles.^{10,11} To determine lateral misalignment of atlas, the BP uses a measurement from the center of “Duff’s Vs”^{10,11} (which are purported to be ossification centers) located on the occipital condyles to points in the atlas transverse foramina^{10,11} (Fig 1). The APOM view uses a measurement from the center of the medial inferior tips of the occipital condyles to points on the lateral mass^{10,11} (Fig 2).

The paucity of investigation concerning the accuracy of the transverse foramen (TF) and lateral mass points has prompted this study because these measurements assume that the TF and lateral mass points are equidistant from a center point on the atlas.

Bilateral differences, if within 1 SD from the mean, could be considered within normal variation when analyzing for lateral misalignment of atlas in relation to the occipital condyles. Should this standard form of quality control be adopted, it will serve to improve the accuracy of the analysis. The purpose of this study is to determine what, if any, asymmetry exists in atlas bone specimens, which could in turn improve the accuracy of determining atlas lateral misalignment.

Methods

The study was approved by the Sherman College of Straight Chiropractic institutional review board. Ten

Fig 1. Base posterior radiograph. Duff Vs indicated by upper arrows, and transverse foramina indicated by lower arrows. Method 1 would call for a dot to be placed on anterior aspect of TF. Measurements taken between Duff Vs and TF on each side. The side of greater measurement would indicate side of possible atlas lateral misalignment. Photograph courtesy of Dr Pat Kuhta.

natural bone atlas (C1) vertebra specimens from humans were obtained from the college’s learning resource center. A Viztek (Jacksonville, FL) digital radiograph unit was used for the imaging procedures. Each atlas vertebra was placed directly on the radiograph Bucky that was parallel to the floor. The bone was positioned on the center of the crosshairs on the Bucky to ensure that it was in the path of the central ray in an effort to minimize distortion (Fig 3). Once the image was recorded in the digital radiographic system, evaluations were made by 2 independent examiners using the system’s software.

In this study, 2 different reference points were used as a center of the atlas vertebra: (1) the anterior-most aspect of the anterior tubercle and (2) the center of the neural ring. The center of the neural ring was established by using the crosshairs tool supplied as a standard component of the Viztek digital radiograph software. For each of the 2 reference points (anterior tubercle and neural ring center), 5 different methods of analysis were performed: measurements were

Fig 2. Anterior-posterior open mouth radiograph. In practice, the medial inferior tips of the occipital condyles and posterolateral aspect of lateral mass would be marked with dots. 2 = lateral aspect of inferior facet (method 2), 3 = lateral aspect of superior facet (method 3), 4 = medial aspect of the superior facet (method 4), and 5 = medial aspect of the inferior facet (method 5). Method 1 not shown here because transverse foramina typically do not show up well on the APOM view. Photograph courtesy of Dr Pat Kuhta.

made between the anterior tubercle or neural ring center and identical points on each side of the atlas for each method.

These identical points, measured from the anterior tubercle or neural ring center, were as follows: TF (method 1), lateral aspect of the inferior articular facet (method 2), lateral aspect of the superior articulating facet (method 3), medial aspect of the superior articulating facet (SAS, method 4), and medial aspect of the inferior articulating surface (IAS, method 5) (Fig 4). For all methods, the examiners selected identical points on the left and right sides of the imaged bone. An example of the line measurements is provided for the anterior tubercle–method 1 approach (TF) (Fig 5).

Mean difference and standard deviation were calculated between the left and right measurements for each method. These differences were also assessed

Fig 4. Atlas specimen showing reference and method points. Digital radiograph of real bone atlas specimen 9. A = anterior center aspect of anterior tubercle reference point. + = center of the neural canal reference point. 1 = method 1, using the anterior aspect of the TF. 2 = method 2, using the lateral aspect of the IAS. 3 = method 3, using the lateral aspect of SAS. 4 = method 4, using medial aspect of the SAS. 5 = method 5, using medial aspect of IAS. The IAS and SAS are superimposed, but IAS = the more anterior facet (between numbers 2 and 5 above). SAS = facet that extends more posteriorly (between numbers 3 and 4 above). Lines are extended from “A” (anterior tubercle) reference point out to points 1 to 5 on each side. The side of greater measurement, if either, would indicate the elongated side. The same type of measurements would be done for the center of the neural canal reference point, that is, from the + out to points 1 to 5 on each side; and the side of greater measurement, if either, would indicate the elongated side.

for statistical significance using the nonparametric Wilcoxon test (2 independent samples, 2 tails) in the Statistical Package for the Social Sciences (SPSS, Chicago, IL; version 14.0).

Fig 3. Placement of bone on Bucky. Model bone used in this photo.

Fig 5. Example of line measurements using the anterior tubercle–TF (method 1) approach for specimen 9. In this example, there is a 1.91-mm difference between the measurements.

Results

Overview

Mean bilateral differences for both examiners and all methods was 0.96 mm (0.99/0.93, Table 1) with 1 SD = ± 0.67 mm (0.70/0.65, Table 1).

Examiner A

Mean differences between left and right measurements for all methods ranged from 0.48 to 1.15 mm (mean, 0.92 mm), ± 0.34 to ± 0.82 SDs (mean, ± 0.65 mm) (Table 1).

Examiner B

Mean differences between left and right measurements for all methods ranged from 0.62 to 1.55 mm (mean, 0.99 mm), ± 0.44 to ± 1.10 SDs (mean, ± 0.70 mm) (Table 1).

Discussion

The 0.95-mm mean difference from side to side, ± 0.67 mm (1 SD), indicates that side-to-side asymmetries up to 1.63 mm could be within normal variation. This does not take into account asymmetry that is likely to be found in the occipital condyles, which should be explored in a follow-up study. Rotation of the atlas (as seen on the BP radiograph) should also be considered because this could result in magnification issues on the APOM radiograph (ie, showing one side larger than it really is). This phenomenon could interfere with the accuracy of an in-office measurement when determining asymmetry for an individual patient. Consequently, the determination of atlas asymmetry would seem to be more accurately determined on the BP radiograph. One

possible option for a center point for the in-office clinician using the BP radiograph would be to use the center of the anterior tubercle as used in the present study. However, not all BP radiographs may show this structure with sufficient clarity. The findings of asymmetry in this study are similar to those of Meseke et al¹² who found asymmetry in vertebral canal and superior and inferior articular facets.

A range of ± 3 SDs is the industry standard for most professions when assessing normal variation in regard to quality control.¹³ However, in this study, because lateral misalignment of atlas will be based on the positive or expanded value of the mean (0.95 mm), an SD of 2 or 3 would result in a range that includes a number less than zero lateral misalignment of atlas. Consequently, a standard deviation of up to 1.4 (± 0.93 mm) would result in an expanded reference range of 0.02 to 1.88 mm, which is appropriate for this study because the measurements for atlas lateral misalignment typically fall within the 1- to 3-mm range.

The generalizability of these findings may be limited to the extent that the sex, age, and other demographics for these specimens at the time of death are unknown. Other limitations include the following: (1) the films of dry bone specimens are not the same as in a living patient; and (2) the positioning of the bone on the film would not be the same positioning when taking a film in a live person that a chiropractor uses in practice; thus, there may be different findings in patients.

Finally, the question may arise as to the clinical significance of slight vertebral misalignment. Indeed, a slight misalignment may not result in neurological irritation. Although it is not the purpose of this article to evaluate the concept of slight vertebral misalignments, there is some evidence that such misalignments may have a clinical impact on the patient. Hoiriis et al¹⁴ found that reduction of the minor misalignment of the atlas, as a component of vertebral subluxation, was related to improvement in health perception. Although

Table 1 Interexaminer differences between left and right sides for 10 specimens, all methods

Examiners	Anterior Tubercle as Center Point			Neural Ring Center as Center Point		
	Mean Difference	L-R (<i>P</i>)	Mean SD	Mean Difference	L-R (<i>P</i>)	Mean SD
A	0.88 mm	.7	0.62 mm	0.97 mm	.9	0.68 mm
B	1.10 mm	.9	0.78 mm	0.89 mm	.8	0.63 mm
Mean	0.99 mm		0.70 mm	0.93 mm		0.65 mm

Comparison of left and right measurements, from a center point, in 10 natural bone specimens analyzed with digital radiography software. All methods are used (5 using anterior tubercle as center and 5 using center of neural ring). Mean difference refers to the difference between left and right measurements; mean SD refers to the mean standard deviation for each examiner (left vs right measurement); L-R (*P*) refers to the statistical significance of the difference between all left and right measurements. Total average difference is $0.99 \pm 0.93/2 = 0.96$ mm. Mean standard deviation is $0.70 \pm 0.65/2 = 0.67$ mm. Allowance for normal bilateral difference is $0.96 \text{ mm} \pm 2 \text{ SDs } (0.67 \times 2 = 1.34) = 2.3 \text{ mm}$. L, Left; R, right.

their study does not settle the question, it does suggest that further research is warranted. Not all chiropractors may subscribe to the concept of slight misalignment being a component of vertebral subluxation. The point of the present study is to show that, for those chiropractors who do look for differences from left-to-right measurements in millimeters for atlas misalignment, the difference may be due to asymmetry and not actual misalignment.

Further research should seek to determine to what extent asymmetry exists for the occipital condyles. Allowing for atlas asymmetry, along with probable occipital condyle asymmetry, would then allow for a total acceptable range of asymmetry when analyzing for lateral misalignment of atlas in relation to the condyles. Further research should (a) include a larger sample size and (b) seek to develop a method for practitioners that would assist them in determining atlas asymmetry for the individual patient according to their respective practice characteristics.

Conclusion

These 10 specimens showed an average difference of $0.95 \text{ mm} \pm 1 \text{ SD}$ (0.67 mm) or 2 SDs (1.34 mm) between the left and right sides of the atlas vertebrae. Differences found on radiographs may be due to asymmetry and not actual misalignment. This would seem to necessitate the determination of atlas symmetry for each patient undergoing radiographic analysis for lateral misalignment of atlas for a vertebral listing to be used when the chiropractic adjustment is administered.

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